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Frequency and Temporal Analysis of Cicada Brood X Sounds

Peter Fuhr[1], Sterling Rooke[2], Elizabeth Piersall[3], Erica Grant[4], Maggie Morganti[5], Thomas J. King, Jr[6], Aaron Wilson[6], Jason Richards[6], William Monday[6]

[1]*Distinguished Scientist, Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA*
[2]*Research Professor, Department of Electrical Engineering and Computer Science, University of Tennessee, Knoxville, Knoxville, TN 37996 USA*
[3]*Graduate Student, Bredesen Center, University of Tennessee, Knoxville, Knoxville, TN 37996 USA*
[4]*CEO/Founder, Quantum Lock Technologies, Knoxville, TN 37996 USA*
[5]*Product Security Researcher, Schneider Electric, Franklin, TN 37067 USA*
[6]*Research Scientist, Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA*

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Abstract - *Sounds emitted by Brood X cicadas in East Tennessee, USA, were recorded on May 31, 2021. Temporal and frequency acoustic analyses of the sounds are presented.*

Key Words: cicada, Brood X, temporal analysis, frequency analysis, acoustic analysis

1. INTRODUCTION

Cicadas are insects that belong to the order Hemiptera (i.e., true bugs). They feed on plant fluids above and below ground. Cicada species fall into two categories: periodical and annual. Seven species of periodical cicadas have been identified, emerging in 13-, 17-, and 21-year cycles [1]. The largest brood (i.e., periodical cicadas of the same cycle) of 17-year cicadas is Brood X, examples of which are shown in Fig. 1. Male cicadas produce the loudest sounds of the insect world. A single male can produce a clicking sound that exceeds 100 dB sound pressure level. This male cicada sound emanates from an organ called the tympanic membrane, which is located on both sides of the body near the base of the wing [2]. The vibrations from this organ generate the sound. Female cicadas make a similar—although less loud—clicking sound with their wings. Figure 2 shows the locations of active cicadas within the United States.


Fig. 1: Brood X cicadas present in East Tennessee, USA (top photograph courtesy of the US National Park Service, lower photograph courtesy of King Photography).

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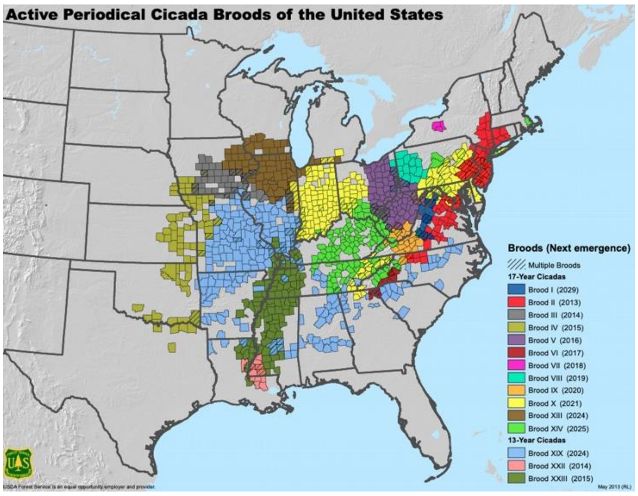

Fig. 2: Cicada locations in the United States [source: US Forest Service].

2. RECORDING

Cicada sounds were recorded at four times on May 31, 2021, in a wooded setting in East Tennessee, USA. The frequency response of the microphone used is shown in Figure 3 (logarithmic scale). The process was to walk into a wooded area and perform multiple 1 min recordings at approximately 1 h intervals. The air temperature at each recording time was measured because cicadas are temperature sensitive [2] and emerge when the ground temperature reaches 17.8°C [3].

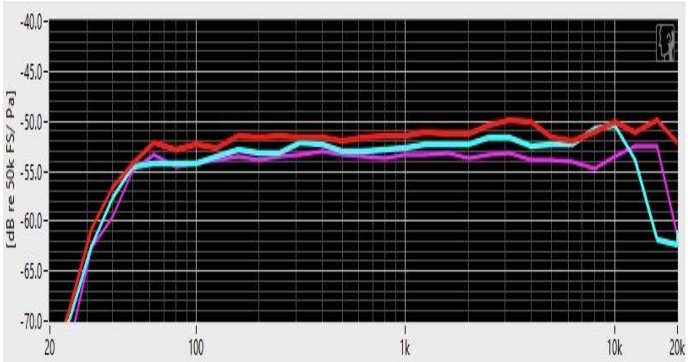

Fig. 3: Microphone frequency response.

Table 1 lists the recording numbers and durations and the corresponding air temperatures.

Table 1. Recording time and temperature (May 31, 2021)

Recording number and time	Air temperature (°C)
1. 09:29	15.6
2. 10:37	17.2
3. 13:04	21.7
4. 14:05	23.9

3. MEASUREMENTS

Temporal plots of the recorded Brood X sounds are shown in Figure 4. Figure 4 (top) is the temporal plot for recording 1, and Figure 4 (bottom) is the temporal plot for recording 2. The time between the amplitude peaks for recording 1 and recording 2 is 5.2 s.

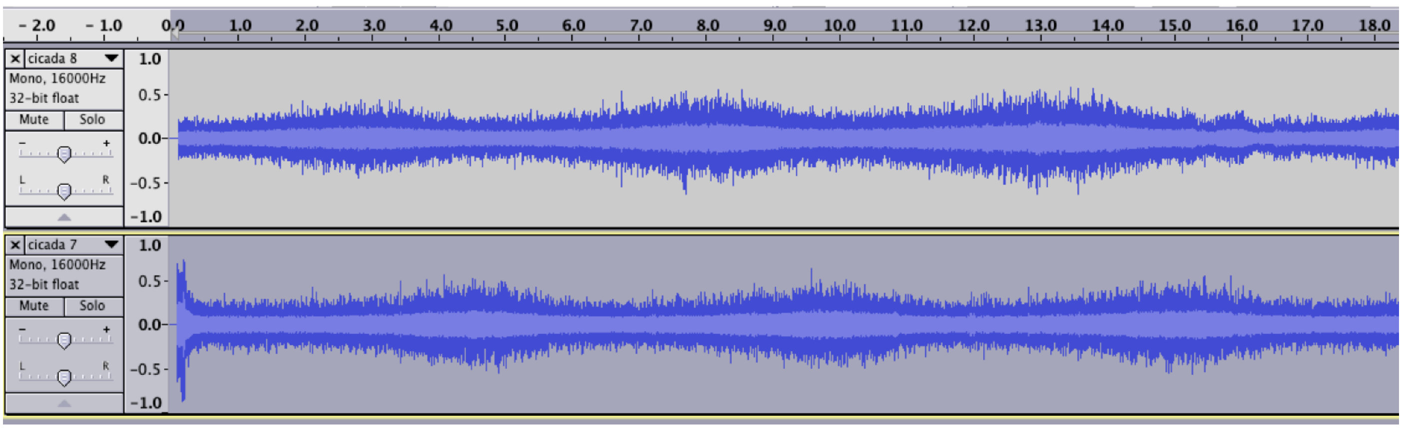

Fig. 4: Temporal recordings of Brood X sounds (top: recording 1, bottom: recording 2).

4. FREQUENCY ANALYSIS

The software application Audacity was used for analysis of the cicada recordings. A Hanning window–based spectrum analysis was applied to the recordings. A frequency analysis plot of the recorded Brood X sounds for recording 3 is shown in Figure 5. Although the measured cicada sounds have a broad frequency range, the recording shown in Figure 5 has a peak that occurs at approximately 6,915 Hz. Slight variations in this peak were observed with each recording, as noted in Table 2.

Table 2. Peak frequency

Recording number	Peak frequency (Hz)
1	5,944
2	6,404
3	6,915
4	6,960

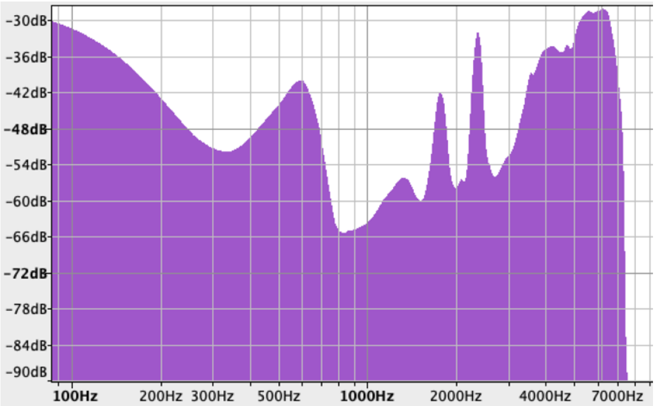

Fig. 5: Frequency analysis of Brood X recording 3.

Similarity between the recorded Brood X sounds was analyzed using the audio equivalent of communications related common-mode-rejection (CMR)[1] [4, 5]. The process, in the analog realm, involved relying on differential operational amplifiers (op-amps) configured as illustrated in Figure 6 with, for example, audio recording #1 being the input into one side of the op-amp while recording #2, being the input to the other side of the op-amp. This configuration proved to be difficult to use due to any misalignment in start time of the two recordings.

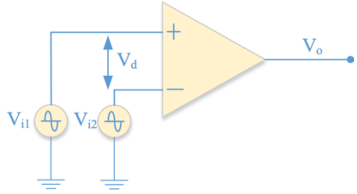

Fig. 6: Analog method of common mode comparison of two recordings.

A digital method of comparing the recorded sounds involved using the audio analysis application Audacity. The process steps are: (1) import two Brood X recordings into Audacity. (2) Apply the "Invert" effect to one of the recordings. (3) Select both recordings, then from the "Tracks menu > Mix and Render". This digital equivalent to the analog common-mode rejection technique works because "adding" (mixing) a recording to the "inverse" of the recording, is mathematically identical to "subtracting" one recording from the other. As shown in Figure 7's CMR comparison of recordings #1 and #3, there is little (distinguishable) difference between the two recordings[2].

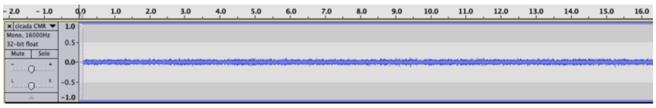

Fig. 7: *CMR comparison of recordings #1 and #3.*

5. SUMMARY

A similar, simple recording and analysis of the Brood XIII (13-year) cicadas is planned for when they emerge from the ground in 2024 [6]. Those future data will be compared with the data presented here. One implication of the loud, broad frequency cicada sounds arises in situations where sensors are being used to measure/monitor sounds emanating from electric grid audio sources. For example, in acoustic monitoring of operational sounds associated with magnetostriction induced acoustic sounds emanating from electrical transformers [7-9], the cicada "output" will obscure the transformer sounds rendering the transformer acoustic monitoring system useless.

[1] Noise (or any unwanted input signal) is common to both inputs, and hence is attenuated via the differential connection.

[2] Indicating consistency of cicada sounds.

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